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TENDER AND REPAIR SHIP
LOAD LIST FORECASTING

by

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TENDER AND REPAIR SHIP LOAD LIST FORECASTING

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I. INTRODUCTION

A. BACKGROUND

The Tender and Repair Ship Load List (TARSLL) authorizes the tender to stock material that supports the tender's industrial mission. For submarine tenders, the TARSLL provides material that supports both its industrial and its resupply mission. Each TARSLL is revised once every three years. For example, the TARSLL currently being used on destroyer tenders (ADs) and repair ships (ARs) was last revised in 1992. Table 1 shows the effective date, number of line items and dollar value of each of the TARSLLs currently in use.

Table 1.[1] Tender and Repair Ship Load Lists in Use

SHIP NAME AND HULL NUMBER	EFFECTIVE DATE	NUMBER OF LINE ITEMS	DOLLAR VALUE
USS Holland (AS-32)***	NOV 91	36,801	$17,855,869
USS Simon Lake (AS-33)*	AUG 95	22,586	$19,619,625
USS L.Y. Spear (AS-36)	AUG 93	28,057	$14,072,545
USS Emory S. Land (AS-39)	MAY 92	26,671	$25,874,751
USS Frank Cable (AS-40)*	SEP 95	33,006	$29,705,596
USS McKee (AS-41)	APR 93	24,312	$22,049,196
Nuclear Submarine Support Facility, New London, CT**	APR 92	32,154	$20,635,929
Fleet Industrial Supply Center, Pearl Harbor, HI**	APR 93	24,312	$22,049,196
USS Shenandoah (AD-44) ***	APR 92	10,682	$1,812,771

* New load list combining support for both submarines and surface vessels.

** Shore based submarine repair activities which maintain a TARSLL.

*** Scheduled for decommissioning in FY 96.

[1] Data provided by SPCC Code 0331.

Presently there are two types of tender load lists: ocean tailored and ship tailored. (The latter are sometimes call "hull tailored.") However, only the USS Shenandoah (AD 44) has an ocean tailored TARSLL. This ship is scheduled for decommissioning in September, 1996. A ship tailored load list is designed to support specific ships assigned to a specific tender. The ship tailored load lists predominantly support submarines and are found on the submarine tenders and at the two shore based submarine support facilities.[2] The load list on the USS Shenandoah is designed to support a large group of ships in a fleet, i.e., in a particular ocean tailored. This type of TARSLL was used in the past on all destroyer tenders and repair ships.

Both types of TARSLL authorize holding inventory of equipment related and non-equipment related material. Equipment related items are those contained in the Allowance Parts List of a supported unit of equipment; and non-equipment related items are general use materials used in support of the tender shops.

This thesis begins by providing background information describing the TARSLL and its purpose. It then describes the TARSLL development process and the current TARSSL model. The component formulae of the model are described. Explanations for assumptions are given and examples have been included for illustrative purposes. Problems with the model are identified and described.

The thesis then describes problems unrelated to the model which have had an impact on the TARSLL development process, including demand recording, candidate selection, churn and the special problems associated with pre-deployment loading. Recommendations for improvements in the TARSLL development process are given, as well as recommendations for improving the demand data from the fleet used to compute TARSLL stock quantities. A short section describing the future of the tender

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[2] Two shore activities currently use the TARSLL: NSSFSO New London CT and FISC Pearl Harbor HI.

fleet and the possible impact of this future on TARSLL development completes the thesis.

B. TARSLL DEVELOPMENT

TARSLL allowances are developed using a combination of information from the Type Commander about specific requested items and historic demand information from tenders and shore based facilities. Rather than tailor specific TARSLLs for individual tenders, one TARSLL is derived for all ships in an ocean based on the average demand for all tenders in that ocean and the demand from the applicable shore based repair facility. Table 2 provides a list of tenders and shore activities providing demand data for the tenders in each ocean.

Table 2. Ships and Shore Activities Providing Demand Data

ATLANTIC TENDERS	PACIFIC TENDERS
USS SIMON LAKE (AS 33)	USS HOLLAND (AS 32)
USS L.Y. SPEAR (AS 36)	USS FRANK CABLE (AS 40)
USS EMORY S. LAND (AS 39)	USS MCKEE (AS 41)
USS SHENANDOAH (AD 44)	FISC PEARL HARBOR, HI
NSSFSO, NEW LONDON, CT	

Note that the USS Shenandoah is scheduled for decommissioning in September of 1996, and that the USS Holland is scheduled for decommissioning in June of 1996. Note also that one submarine tender in each ocean (USS Simon Lake and USS Frank Cable) carries load list material in support of both submarine and surface ships.

At the start of the TARSLL development process, personnel at the Navy Inventory Control Point (NAVICP) obtain the list of ships to be supported by the TARSLL. This list is sometimes referred to as the "hull mix." This list may contain all ships in a particular fleet (in the case of the ocean tailored load list) or may contain a smaller set of ships specified by the Type Commander (in the case of the hull tailored TARSLLs).

The hull mix is used in conjunction with Level A of the Weapons System File (WSF) (maintained by the NAVICP) to obtain a list of the equipment aboard each ship in the mix. Once this list of equipment has been obtained and the duplicates (between ships) removed from it, Levels B and C of the WSF are used to obtain the stock numbers for all of the stock numbered items in each unit of equipment in the list. This process yields a list of candidate items with stock numbers (NIINs or NICNs) from the Weapon Systems File.

Generally, the items on the WSF candidate list turn out to be depot level repairable items or equipment related consumable items. Note that during the preparation of some load lists, NAVICP personnel have examined the WSF entry date for NIINs and NICNs that will be new to the particular load list. For load lists where this has been done, items whose entry date is older than two years are excluded from the list. The rationale for doing this is that these items may be obsolete if they have not been in previous load lists and have a past history of zero demand.

The next step in the TARSLL development process is to create an additional NIIN/NICN candidate list using the demand history file for the Combat Logistics Force (CLF). Using the unit identification codes (UICs) for the ships in the hull mix, the requisitions in the CLF demand history file are screened. NIINs and NICNs that show no demand from ships in the hull mix are excluded from this "CLF candidate list." The requisition history for the most recent eight quarters is normally used when

creating the CLF candidate list, although the Type Commander can specify a different, usually shorter, period of time. For some load lists, NIINs and NICNs are excluded if their demand has consisted of one or fewer requisitions during the last eight quarters. For other load lists, this criteria is set at just zero requisitions. Either way, the result of this process is an additional list of candidate NIINs and NICNs. Note that the CLF candidate list is the source of most of the non-equipment related consumable items that end up in the load list.

The CLF candidate list and the WSF candidate list are merged and duplicates are eliminated. The resulting list carries with it the demand history for the NIIN or NICN, unless the item came from the WSF candidate list and had a CLF demand history of zero units. In this case, the best replacement factor (BRF) is carried in the merged list.

The next step in the load list development process determines whether the items on the merged list can be replaced aboard the tender. If the item isn't replaceable aboard the tender, it is excluded from the load list. If it is replaceable, a series of so called "range rules" are applied. These rules make use of historical demand data if it is available for the item, otherwise the best replacement factor (BRF) value is used.

The range rules generally work in the following manner. The demand in units for the most recent 8 quarters is averaged for the item in question (or this quarterly average is estimated using the BRF[3]). If this quarterly average is below a specified value (called the "range cut"), the item is excluded from further consideration. The range cut values are different for each tender, and are also a function of the item type

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[3]The Best Replacement Factor is an estimate of the mean hours before failure provided by the manufacturer of the item. It is used to estimate quarterly demand for a newer item by multiplying the Best Replacement Factor (BRF) value by the tender population and dividing by four.

and whether or not the item was included in the previous load list for that tender. There are three item types used in conjunction with the load list: depot level repairable items (DLRs), equipment related (ER) consumable items, and non-equipment related (NER) consumable items. Table 3 shows the range cut values for all tenders currently in the Navy, by item type, and by whether the item is new to the load list or a "retention" item, i.e., was in the previous load list for the tender.

Table 3. Range Cut Values for Current Tender Load Lists

TENDER	LAC	Load List Date	RANGE CUT VALUES					
			New Items			Retention Items		
			DLR	ER	NER	DLR	ER	NER
USS Shenandoah	AD 44	Apr 92	11	15	24	2	3	3
USS Holland	AS 32	Nov 91	4	4	4	1	1	1
USS Simon Lake	AS 33	Aug 95	2	3	4	2	3	4
USS L. Y. Spear	AS 36	Aug 93	4	4	4	1	1	1
USS Emory S. Land	AS 39	May 92	4	4	4	1	1	1
USS Frank Cable	AS 40	Sep 95	2.5	5	7	1	1	2
USS McKee	AS 41	Apr 93	4	4	4	1	1	1
NSSFSO New London		Apr 92	4	4	4	1	1	1
FISC Pearl Harbor		Apr 93	4	4	4	1	1	1

At this point *overrides* are added to the candidate list. Overrides include items requested by the Type Commanders and any new equipment installations which require support. The TARSLL model calculations are then applied to the final candidate items and a preliminary TARSLL is produced. The preliminary TARSLL

is sent to the Type Commanders and to the tenders for review.[4] Type Commander requested changes are reviewed by SPCC and are usually implemented.[5] After changes have been agreed upon and implemented, the TARSLL is forwarded to NAVSUP for funding approval. Once funding has been approved, the completed TARSLL is sent to the tender for implementation.[6]

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[4]Most tenders do not recommend changes to the preliminary TARSSL. Those that do recommend an average of 400 changes, almost all of which are requests for additions. Requested changes are implemented if the Type Commander concurs. [Ref. 1]

[5]While changes requested by the Type Commanders are usually implemented, SPCC can refuse to include items. Such refusals are usually a result of very high unit cost [Ref. 5].

[6]The entire TARSLL development process takes approximately six months to complete from initial candidate identification through reviews and finished product.

II. CURRENT TARSLL MODEL

A. BACKGROUND

The TARSLL shows the range and depth[7] of items that each tender and repair ship is authorized to carry. Each fleet (Atlantic and Pacific) has a separate TARSLL. The TARSLL candidate file[8] consists of Combat Logistics Force (CLF) demand and Weapons System file (WSF) data for ships the TARSLL supports. There are primarily two ways for an item to become a TARSLL candidate. One way is to have demand recorded against a destroyer tender (AD) or a repair ship (AR) in a two year period. The other way is for the item to be part of an APL and coded intermediate level removal and replacement. The TARSLL model selects items to carry, computes the depth for each selected item and predicts the effectiveness of the list.

B. TARSLL COMPUTATION

The first step in the TARSLL computation is to determine the types of ships the tender will be supporting and pulling a list of candidate APL's for those ship types from Level A of the Weapons System File. Component parts for the equipment identified in Level A are then compared to Level C to determine if the items are common to a CNO determined number of ships. In an effort to broaden the range of items carried, the number of ships needed to qualify an item for inclusion is currently one [Ref. 1]. The item is then checked to determine whether the stock number is active. Non-active stock numbers are removed from further consideration. Stock numbers are then checked to determine the level of maintenance required. If the item can be replaced at the shipboard level or the Intermediate Maintenance Level (on the

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[7]Range refers to the number of line items carried; depth refers to the quantity of each line item carried.

[8]UICP Application Operation E17 [Ref. 1].

tender), it is included as a possible candidate. The next step in the process is the estimation of an item's demand. The next section gives the formulae that are used.

1. If Demand History Is Available

If demand history is available for the item, the first step in determining a load list quantity is to compute an estimate of the mean quarterly demand. This estimate is called the quarterly average demand (QAD). An estimate of the standard deviation of quarterly demand is also calculated from the demand history. The QAD and the standard deviation are computed using demand data from all tenders in a particular ocean.

$$\mu = \frac{\sum_{1=1}^{N} D_i}{N}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (D_i - \mu)^2}{N-1}}$$

where D_i = Demand during the *i*th quarter

N = Number of quarters of demand history (usually 8)[9]

μ = Estimated quarterly average demand

σ = Estimated standard deviation of quarterly demand

[9]This number may change to include or exclude demand periods if the list was being prepared for a special operation. [Ref. 1]

2. If No Demand History Is Available

If no demand history is available for an item, as in the case of items required to support newly installed equipment, an estimated QAD is calculated using the best replacement factor[10] and the installed population of the item.

$$\mu = \frac{BRF}{4} \quad [(POP_S)K_S + (POP_T)K_T]$$

$$\sigma = \begin{Bmatrix} 1.6\,\mu & \text{if } \mu \geq 1.0 \\ 2.1\,\mu & \text{if } \mu < 1.0 \end{Bmatrix}$$

where POP_S = Size of the installed population that can be removed/replaced by ship[11]

POP_T = Size of the installed population requiring tender to remove/replace[12]

K_s = Percent of total support provided by the ship[13]

K_T = Percent of total support provided by the tender

μ = Estimated quarterly average demand

σ = Estimated standard deviation of quarterly average demand.

Items that can be supported at the shipboard level are still supported by the tender approximately 10% of the time for various reasons, such as during an overhaul or as part of a larger repair job [Ref. 2].

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[10]The best replacement factor is an estimate of an item's useful life calculated by the manufacturer.

[11]POPs is that population of the item that is used in applications in which the Maintenance Code indicates that the lowest level at which the item can be removed and replaced is the organization's (shipboard) level.

[12]The same as POP_t except the item can be removed and replaced at the intermediate (tender) level.

[13]K_S is currently set at 0.10 and K_t is currently set at 0.90 [Ref. 5].

3. Computing QAD and Standard Deviation for One Tender

Once the QAD and standard deviation have been computed for the ships in an entire ocean, the QAD and standard deviation for one tender are calculated using the following formulae:

$$\mu_T = \mu K T$$

$$\sigma_T = \sigma K \sqrt{T}$$

where K = Percent of ocean's total demand satisfied by the tender

T = Length of the support period, typically one quarter

μ = Estimated quarterly average demand for the particular ocean

σ = Estimated standard deviation of quarterly demand for the ocean

μ_T = Estimated quarterly average demand for the tender

σ_T = Estimated standard deviation for the tender

4. Protection

A stock out risk value is calculated which determines the protection level for the item. It is calculated using the unit cost of the item, the average requisition size, and a quantity called the *control knob* which can be adjusted to increase or decrease the protection level. The following formula is used to compute the risk value, i.e., the probability of stock out that will be used in the calculation of authorized item depth.

$$\alpha = \frac{\lambda p A}{\mu}$$

where: α = risk, i.e., probability of a stock out

p = unit price of the item

μ = Estimated quarterly average demand

A = Estimated average requisition size

λ = value specified for the control knob ($\lambda \geq 0$)

For some items, this calculation yields a number that is greater than 0.97725. For other items, this calculation yields a number that is less than 0.02275. While there is nothing particularly special about these specific numbers, NAVICP personnel do wish to limit the model from stocking material for extremely high or extremely low stockout probabilities. Therefore the actual protection level (PROT) used in item depth computations is forced to fall between 0.02775 and 0.97725:

$$PROT = 1 - \left\{ \begin{array}{ll} 0.02275 & \text{if } \alpha < 0.02275 \\ \alpha & \text{if } 0.02275 \leq \alpha \leq 0.97725 \\ 0.97725 & \text{if } \alpha > 0.97725 \end{array} \right\}$$

5. Assumptions

It is assumed that possible demands are best represented by the normal distribution.[14] Therefore the an item's allowance depth is calculated from:

$$D = \mu + z\sigma$$

where: D = Load list stockage quantity for the item

μ = Estimated quarterly average demand

[14]SPCC Code 0431 states that the normal distribution best describes observed demand [Ref. 2].

σ = Estimated standard deviation of quarterly demand

z = Value of the normal variate that yields the calculated protection level (PROT)

6. Net Effectiveness

The model computes a figure for expected units short. This figure is used to determine net effectiveness. The expected units short is computed as follows:

a. Compute t Value

The first step in calculating effectiveness is to compute a "T" Value.

$$T = \frac{D - \mu}{\sigma}$$

Where: D = Load list stockage quantity for the item

μ = Estimated quarterly average demand

σ = Estimated standard deviation of quarterly demand

b. Compute T_0

The T value represents the number of standard deviations of quarterly demand contained in the safety stock for the item. The constraints shown below are applied to T. The resulting value is labeled T_0.

$$T_0 = \left\{ \begin{array}{lr} 37 & \text{if } T > 37 \\ T & \text{if } -37 \leq T \leq 37 \\ -37 & \text{if } T < -37 \end{array} \right\}$$

c. *Compute Actual Stock Out Probability (RISK)*

If $T_0 > 0$, the actual probability of a stock out (RISK) is calculated using the following numerical approximation to the normal distribution:[15]

$$RISK = \frac{1}{2(1+0.196854\ T_0+0.115194\ T_0^2+0.000344\ T_0^3+0.019527\ T_0^4)^4}$$

Note that if $T_0 < 0$, then $-T_0$ must be used instead of T_0 in this approximation. In this case, the probability of a stock out is given by 1-RISK.

d. *Compute T_1*

$$T_1 = 0.3989\, e^{\frac{-T_0^2}{2}}$$

e. *Compute V, U and Expected Units Satisfied (S)*

$V = \sigma\,(T_1 - T_0(\mathrm{RISK}))$

$U = \text{minimum}\ \{\mu, V\}$

The model then computes Expected Units Satisfied (S) for each item, which is:

$S = \mu - U$

---

[15]This numerical approximation for the normal distribution was obtained from the Department of Commerce, National Bureau of Standards Applied Mathematics Series 55, Handbook of Mathematical Functions, With Formulas, Graphs and Mathematical Tables, Milton Abramowitz and Irena A. Stegun, ed., 932 (Washington, DC: U.S. Government Printing Office, 1964). The Handbook claims that this approximation has an error term whose absolute value is less than 2.5×10^{-4}. [Ref. 6]

To get the overall effectiveness for the TARSLL, the model adds the expected units satisfied across all items and divides this quantity by the sum of total demand across all items. The parameter λ can be adjusted at this point and the model rerun to increase or decrease the overall effectiveness.[16]

7. Discussion

For each item with a demand history the model sums eight quarters of demand. For items with no demand history the model calculates an expected quarterly average demand using the Best Replacement Factor.[17] The model multiplies this expected quarterly average demand by eight to estimate the expected usage for a two year period. The model compares this forecast to the range cut, which is currently a frequency of demand of one requisition in a two year period. As a result of these computations many items which were formerly carried in the load list will no longer qualify and many new load list items will be identified. This will cause the tender to generate many new requisitions and will cause many items carried to become excess. This effect is called *churn*. To control churn, the model retains in the load list those items having one demand or one APL application during the history period used to build the load list. The model normally uses a demand history of eight quarters. However, longer or shorter periods can be used for special circumstances, such as a major wartime exercise.

For items passing the range cut or retained by the churn rule, the model uses the λ values to control each item's risk of stock out. These parameters can be adjusted by the user to decrease or increase the risk of stockout if necessary. One reason for decreasing the risk of stock out would be if the item is difficult to procure or has an extremely long order and issue lead time. The model uses the normal distribution to

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[16]Lambda (λ) must be a positive number, but has no upper limit [Ref. 5].

[17]See formula in Chapter II, Section B, paragraph 2.

describe the behavior of a random demand process. This description is combined with an inventory model to estimate the load list quantity that gives the computed protection. Net effectiveness is computed using this protection level. The λ value for different items may vary greatly. Generally the value of λ is selected to achieve a net effectiveness of 85%.

III. ANALYSIS OF CURRENT MODEL

The current TARSLL model has been used since it was developed in 1972 and has only recently come under close scrutiny. Several problems have been identified, including the model's failure to take into account the number of times an item is requisitioned, and its failure to provide a load list which adequately reflects the quantities of materials required for an extended deployment where normal supply channels are not available.

A. DEMAND TIMING AND FREQUENCY OF DEMAND

The TARSLL model does not take demand timing or frequency of demand into account. It treats one requisition for 80 units the same way it treats 8 requisitions for 10 units. This can cause an item with a large, one time demand quantity to be picked up as a TARSLL candidate. SPCC feels that this is not a problem because the formula for calculating the protection level should exclude most of these items from consideration as TARSLL candidates. The protection formula is:

$$PROT = 1 - \frac{\lambda p A}{\mu}$$

Where: p = unit price

μ = quarterly average demand

A = requisition size

λ = control parameter

If the computed protection level is greater than 0.50, then the corresponding positive normal variate (z) is calculated from the normal distribution. If the protection level is less than 0.50, then the corresponding negative normal variate (z) is calculted. The depth calculation is then made:

$$Depth = \mu_T + z\sigma_T$$

Where: Depth = load list quantity

The formula above works well for demand histories that can be described by the normal distribution. However, some demand histories are not accurately described by the normal curve and this is where the model fails to produce a meaningful load list quantity. The following example illustrates this point:

1. Normally Distributed Demand

a. Scenario A

QUARTER	OBSERVED DEMAND
1	5
2	4
3	8
4	3
5	6
6	2
7	7
8	4

TOTAL DEMAND 40 [Ref. 4]

$$\mu = \frac{\sum_{i=1}^{8} D_i}{8} = \frac{40}{8} = 5.0$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (D_i - \mu)^2}{N-1}} =$$

$$= \sqrt{\frac{(6-5)^2+(4-5)^2+(8-5)^2+(3-5)^2+(6-5)^2+(2-5)^2+(7-5)^2+(4-5)^2}{8-1}} = \sqrt{\frac{30}{7}} = 2.0702$$

Number of tenders in ocean area = 6

K = % of total demand for 1 tender = 1/6 = 0.166667

T = Length of support period = 1 quarter

$$\mu_T = \mu K T = 5(0.166667)(1) = 0.8333$$

$$\sigma_T = \sigma K \sqrt{T} = (2.0702)(0.166667)(1) = 0.3450$$

Unit price = $1.14 per unit

Average requisition size = 1

$\lambda = 0.05$

$$PROT = 1 - \frac{0.05(1.14)1}{0.8333} = 1 - .0684 = 0.9316$$

Protection of 0.9316 is equivalent to 1.5 Standard Deviations under the normal curve

$$Depth = \mu_T + 1.5\sigma_T = 0.8333 + 1.5(0.3450) = 1.3508$$

Where: Depth = Load List Quantity

Thus we see an allowance quantity of one unit would be stocked to support the tender's quarterly average demand of 0.8333 units. (Normal rounding to the nearest integer is used.) In this case the model appears to do a reasonable job of selecting an allowance quantity.

2. Demand Which Cannot Be Described By the Normal Curve

a. Scenario B - One Large Requisition With No Subsequent Demand

In this scenario there is one requisition in the first quarter of the demand history for 40 units with no subsequent demand. The average requisition size therefore is 40. All other parameters remain the same as the case described by the normal distribution of demand in subparagraph (1).

1st QTR $D_1 = 40$

2nd QTR D_2 through 8th QTR $D_8 = 0$

Total Demand = 40

$$\mu = \sum_{i=1}^{8} \frac{D_i}{8} = \frac{40}{8} = 5.0$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{8} (D_i - \mu)^2}{8-1}} =$$

$$= \sqrt{\frac{(40-5)^2 + (0-5)^2 + (0-5)^2 + (0-5)^2 + (0-5)^2 + (0-5)^2 + (0-5)^2 + (0-5)^2}{8-1}} = \sqrt{\frac{1400}{7}} = 14.1421$$

K = percent of total demand for 1 tender = 1/6 = 0.166667

T = Length of support period = 1 quarter

$$\mu_T = \mu KT = 5.0(0.166667)(1) = 0.8333$$

$$\sigma_T = \sigma K \sqrt{T} = 14.1421(0.166667)1 = 2.3570$$

Unit Price = \$1.14

Average requisition size = 40 units

$\lambda = 0.05$

$$PROT = 1 - \frac{0.05(1.14)40}{0.8333} = 1 - 2.7361 = -1.7361$$

Since the protection level is supposed to be a probability value, a value of -1.7361 makes no sense. Since this situation can occur occasionally, the model has a pair of constraints that sets a minimum protection level of 0.02 and a maximum of 0.98. In this example the protection level will thus be set to 0.02. A protection level of 0.02 yield a negative z value from the normal distribution of -2.06; thus the load list depth calculation will yield:

$$Depth = \mu_T + 1.5\sigma_T = 0.8333 - 2.06(2.3570) = -4.0221$$

Since a negative depth makes no sense, the allowance quantity used is zero. The model thus handles a single requisition for a large quantity in an effective manner, correctly advising that the item not be carried.

b. Scenario C - Several Requisitions in the First Quarter of Demand History With No Demand in Subsequent Quarters

In this scenario all parameters are identical to scenario A with the exception that average requisition size is now four units instead of 40. All demand is recorded in the first quarter. All calculations will be the same until the point in which we calculate protection.

$$PROT = 1 - \frac{0.05(1.14)4}{0.8333} = 1 - 0.2736 = 0.7264$$

A protection level of 0.7264 corresponds to z = 0.602 so:

$$Depth = \mu_T + 0.602\sigma_T = 0.8333 + 0.602(2.3570) = 2.2522$$

In this example, the model would recommend a load list quantity of two units. This is double the quantity that the model would recommend if the 40 units of demand were distributed in accordance with a normal distribution, as in scenario A.

While this type of scenario is the exception rather than the rule, it does occur often enough to have a negative impact on TARSLL effectiveness over time. The key is the average requisition size. As average requisition size goes up in relation to total demand, the likelihood of the item being added to the load list goes down. While this will eliminate one time requisitions from consideration, no weight is given to the timing of demand. Thus a flurry of small requisitions submitted eight quarters ago is treated in the same manner as a more even distribution of demand over the eight quarters.

This is a problem because each job worked by the repair department is assigned a separate Job Control Number, thus the overhaul of 10 water pumps will be assigned 10 Job Control Numbers. If the same washer is required to complete the 10 separate water pump jobs, the tender must generate 10 separate requisitions for accounting purposes rather than one requisition for the entire quantity of washers needed. If the repair technician does not specify this is a non-recurring requirement,[18] the washer becomes a TARSLL candidate which is likely to be selected as a load list item even though it will probably never be needed again.

[18]When ordering material, the technician has the option of specifying whether the demand for the item is recurring or non-recurring. If this part of the ordering screen is left blank, SUADPS defaults to recurring demand.

It should be pointed out that the tenders themselves are partly responsible for this problem. A one time requirement should be recorded as a non-recurring demand in the tender's demand histories. If this were done faithfully, these items would not become TARSLL candidates. However, in the day to day tender repair operation many feel it is better to record all demands as recurring, "just in case". In most cases the storekeeper has no way of knowing whether a requisition is a one time requirement or not. The Shipboard Uniform Automated Data Processing System (SUADPS) defaults to recurring demand, thus demands will automatically be recorded as recurring unless special effort is made to record them as non-recurring. To correct this problem the model can be adapted to identify this type of demand and flag it for separate review.

The perceived reduction in TARSLL effectiveness has resulted in the Commander, Naval Surface Forces, Atlantic Fleet (COMNAVSURFLANT), requesting a review of the TARSLL model to correct this problem which claims "results in tender repair departments reporting utilizing as little as 17 percent of available TARSLL."[19] [Ref. 3]

The problem is so acute that COMNAVSURFLANT has requested that SPCC cease development of the 1995 TARSLL until this issue is resolved. Millions of dollars in stock fund assets are tied up in TARSLL stock, which also consumes badly needed storage space.

Items with no demand history pose a similar problem. The model's tendency is to include them rather than exclude them. This is a result of its reliance

[19]A review of AT-Code 2 (Load List) items onboard USS YELLOWSTONE (AD-41) done in November of 1994 revealed that of 7,586 AT Code 2 items carried, 5,298 experienced zero demand in the previous 8 quarters. Similar results were reported by the other Atlantic Fleet tenders per Ref. 3, however, the exact figures for other tenders are not available.

on the installed population as a key component in its QAD computation:

$$\mu = \frac{BRF}{4}[(POP_S)K_S + (POP_T)K_T]$$

Where: POP_S = Population of item that can be removed/replaced by ship

POP_T = Population of item requiring tender to remove/replace it

K_s = percent of total support provided by the ship

K_T = percent of total support provided by the tender

A small BRF reduces the QAD, however the BRF for new items is only an engineering estimate and manufacturers have an interest in providing a low BRF figure. Items with a large installed population will tend to have a large estimated QAD as a result of this computation.

IV. ADDITIONAL PROBLEMS UNRELATED TO THE MODEL

A. DEMAND RECORDING

The creation of a TARSLL starts with the Demand History Files from the appropriate tenders for each fleet. Some of the problems currently being experienced with the TARSLL can be traced back to this source. A brief description of the material ordering cycle will be used to identify several problem sources.

1. Ship's Uniform Automated Processing System (SUADPS)

The Ship's Uniform Automated Processing System (SUADPS) is the system used by tender supply departments to order, receive, store and issue material and to maintain Special Accounting Class 207 (SAC 207) financial records as well as the ship's financial record. The Maintenance Resource Management System (MRMS) is the system used by tender repair departments to manage work packages and maintenance jobs. These two systems can communicate with each other in a limited fashion. MRMS can pass its material requirements to SUADPS for requisitioning and can track the material requisitioned by retrieving status information from SUADPS. The demand history process for the TARSLL begins in MRMS.

A ship being repaired submits a package of jobs they would like the tender to accomplish during the ship's upcoming availability. The repair department reviews these jobs and then sends a team from its Planning and Estimating division (P&E) to the ship to actually look at the jobs requested. As a result of these reviews the tender determines which jobs it will be able to do and what materials will be needed. The Planning and Estimating personnel submit the original requirements for materials to MRMS. MRMS passes this information to SUADPS for requisitions to be produced. Additional requirements for material will be identified and the material requisitioned by the tenders various repair shops as they do the repair work. Before the requisitions

are produced, the supply department reviews the material requirements for availability of the material and funding. Once approved, the requisitions are generated by SUADPS.

When ordering materials through MRMS, the program requests information on whether the requirement is a recurring or non-recurring requirement. Repair Parts Petty Officers (the repair department personnel responsible for material requisitions within each shop) receive training on how to order material and track its status. Their training includes information about how to determine whether a requirement is recurring or non-recurring, however the RPPO often cannot determine the likelihood of recurrence of demand for a particular item given the information he has. When in doubt recurring demand is the preferred input. In fact if no action is taken to specifically identify the demand as non-recurring at this point, the program will default to recurring demand. When the requisition is passed to SUADPS, the requisitions will also be coded as a recurring demand and will be recorded as such in the SUADPS demand history file. If material is ordered for a one time requirement and no action is taken by the personnel in planning and estimating to record it as such, this material will become a TARSLL candidate. Most material ordered this way will be weeded out by the TARSLL model; however, if an extremely large quantity of this material is ordered, it may pass the model reviews and be placed in the TARSLL. As a result of a one time requirement from one tender, all tenders in that ocean will now be required to carry that material.

A different problem arises when repair shops maintain *shop spares*. Shop spares are materials left over from previous repair jobs which can potentially be used in future jobs. The accumulation of these spares has several causes, including over-estimation of previous material requirements, parts culled from broken components removed from ships, and material loaded in bulk to meet anticipated deployment

requirements.[20] The use of shop spares usually escapes demand recording and is difficult to track. If the quantity on hand is large enough, several years can pass before replacement material is ordered through the supply system which finally causes the demand to be recorded. Generally the material that repair shops want to keep on hand as shop spares is the material that they perceive is the most difficult to get, primarily material that has a long procurement lead time. Parts culled from broken components should be recorded and a system is in place to capture this demand, however it is rarely used by shop technicians. This could be because they are not aware of the importance of capturing this data, or how doing so will benefit them.

Another problem is caused by the pre-deployment loadout. Pre-deployment loadout refers to requisitioning materials to bring the on hand quantities of material up to the load list high limits and to bring material onboard which the repair department anticipates using during the deployment in quantities in excess of the load list high limits. The repair department requirements that are in excess of established load list high limits involves primarily non-equipment related material which the repair department anticipates will be used in large quantities and which cannot be shipped via aircraft due to size and weight constraints. Examples of non-equipment related material which can not be shipped via aircraft include various grades of sheet metal and lumber. Equipment related materials which have recently (since 1992) been pre-deployment loaded are primarily those parts used to support gas-turbine engines, which are relatively new and are installed on limited numbers of ships.

[20]Bulk material requirements are often excessive because the repair department prefers to err in favor of having too much material vice too little.

2. Problems Caused By Tender Operating Procedures

Recording all demands as recurring causes the model to include material in its candidate list that should be excluded. Although a one time require-ment for a small quantity will be excluded by the range cut parameters, a large one time requirement for a large quantity may pass the range cut and be included as a TARSLL candidate.

Shop spares are items which should be included as candidates in the model, but are not because no demand has been recorded by the tenders. This is not a problem with the model, but a procedural problem on the tender. These problems lead to a positive feedback loop in which repair department technicians perceive that the load list is inadequate and therefore increase the number of shop spares so as not to be caught short of the material necessary to complete a job. Consequently the demand history for these items is not carefully kept, and they tend to be carried in amounts that are inadequate or not carried at all. This reinforces the technicians perceptions and encourages him to hold more shop spares.

Pre-deployment loadout of material requested by the repair department in excess of TARSLL high limits causes the model to use inflated demand requirements when choosing candidates. Again this is a problem caused by the tenders, not by the model itself. Finally the model is not responsive enough to changing technologies as in the case of gas turbine engine support. It is not clear whether this problem is the result of SPCC failing to act in a timely manner, or the Type Commanders not identifying the problem early enough.

B. CANDIDATE SELECTION

The TARSLL candidate selection process is completed almost in its entirety by personnel at Ship's Parts Control Center (SPCC). The bulk of the input used for this selection process is derived from the Weapons Systems Files (WSF). Fleet

personnel do not review the load list until a "preliminary" TARSLL has been generated.

Throughout the TARSLL's life, problems are identified by tender personnel in the fleet. These problems are passed to the Type Commander who then brings them to the attention of SPCC for correction. SPCC releases interim corrections to the fleet throughout the life of the TARSLL and rectifies all of the identified problems in the next TARSLL released.

The problem with this process is that ships are likely to bring only the most onerous of problems to the Type Commander's attention. The technician in the repair shop usually finds local solutions to the majority of his material problems, by means of shop spares, substitutions or by fabricating parts from raw materials. The technician is only likely to complain when he cannot devise a local solution. If the problem threatens the repair ship's production goals, it will be brought to the supply department for resolution. Typically the supply department will take extraordinary measures at this point to procure the needed material in order to meet the production schedule. These extraordinary measures include calling the item manager at SPCC for assistance, or procuring the part from sources outside the supply system (open purchase). If the supply department is successful, the problem is considered resolved. There is little incentive at this point to determine why the part was not available in the first place. In order for a parts problem to be considered serious enough to be brought to the Type Commanders attention as a TARSLL problem, the problem usually must occur fairly frequently. Intermittent problems are not usually remembered or reported, but they should be for demand history purposes. A short report identifying any item which causes a work stoppage could be required by the Type Commanders to capture this information.

When the Type Commander gets the preliminary TARSLL, the problems that have been reported from tenders in the fleet are addressed as overrides. However, only a small fraction of all the problems have been brought to the Type Commanders attention; most problems have been successfully dealt with by the tender and therefore not reported. The Type Commander sends the preliminary TARSLL to the tenders for review. This review is usually done by the supply department. The technician in the shop who is dealing with the parts problems on a daily basis is usually not asked about any problems he might have experienced with certain parts. The supply department will probably remember some particularly difficult to procure parts and may address those in their review of the TARSLL, but they will probably not remember the majority of the problem items.

Neither the ship or the Type Commander has the time nor the resources to review every item, nor should a comprehensive review be necessary on an annual basis. However without a comprehensive review prior to the release of a new TARSLL every three years, the problems may accumulate over time to the point where the TARSLL has lost its usefulness as a load list [Ref. 3].

C. CHURN

Churn is defined as the amount of material added to and deleted from a load list as a result of implementing a change in stocking requirements. When new line items are brought into stock, they must be requisitioned, received, and stored. While the requisition process is usually automated, the receiving and storage functions are still done manually. When items previously carried are dropped, they must be pulled, packaged, and offloaded. They must then be turned back into the stock fund for reissue, or in the case of obsolete items and some raw materials, they must be turned in as scrap materials. The addition and deletion of significant amounts of material over a short period of time is extremely labor intensive and often strains the supply

department's manpower resources. Therefore, efforts are made at all levels of the supply system to reduce churn.

SPCC's TARSLL model sets range cuts specifically to reduce churn. For new items to be added to the TARSLL, they must have experienced the following total quantities demanded during the previous eight months:

Depot Level Repairables: 11 units.
Equipment Related Consumables: 15 units.
Non-equipment Related Consumables: 24 units.

For items already on the TARSLL the following total quantities demanded must be recorded:

Depot Level Repairables: 2 units.
Equipment Related Consumables: 3 units.
Non-equipment Related Consumables: 3 units.

Items which do not meet these requirements are dropped from the TARSLL.

While these range rules reduce churn to some extent, current indications are that special measures may be necessary in order to reduce the amount of excess stock held [Ref. 3]. A one time project to gather data on excess items for review and off load approval from SPCC would accomplish this task. SPCC plans changes in the range rules to address the churn issue.

D. DEPLOYMENT

The TARSLL was designed as a general purpose load list. Ideally it should work whether the tender is in home port or deployed overseas. In practice, the TARSLL performs best for ships in home port with ready access to the defense supply support system and the availability of local contracting and procurement facilities. During overseas deployment the lack of these facilities makes careful pre-deployment load planning a necessity.

Pre-deployment load planning is made difficult by the lack of information available concerning the number and types of ships to be repaired during the deployment. While ships which will be tended early in the deployment are usually known, information about what work is to be done beyond the first two months of the six month deployment is not usually available.

The tender's goal is to complete as many work packages as possible during the deployment. Towards that goal, the repair department would like to have material on hand to complete any conceivable job. Considerations in the choice of materials include available storage space, cost to the stock fund and likelihood of use. Close coordination between the supply department and repair department is necessary to see that the needs of each are met. The repair department wants to maximize material carried, while the supply department wants to minimize excess material in stock at the end of the deployment. The TARSLL as currently produced does not make this trade off successfully.

To address this problem, most tenders start planning months before the actual deployment date. Typically the supply department requests information from the repair department concerning what materials they feel are critical to the success of the deployment and in what quantities. This list is compared to recorded demand for the items the repair department requests and discrepancies between what the repair

department wants and what demand history shows are worked out. Generally discrepancies can be attributed to the repair department using shop spares without reporting the demand, and to newly identified requirements which have not had time to show up in the demand history.

Most of the items requested by the repair department are bulk raw materials, such as sheet metal, lumber, piping and hoses, although specific repair parts are requested as well. Bulk materials are loaded primarily due to lengthy shipping times experienced when ordering for overseas shipment. Some tenders request specific repair parts funding (Repair of Other Vessels (ROV) Funds) from the Type Commander to procure these bulk materials, while others procure the materials for stock using Defense Business Operating Funds (DBOF).

Special requirements which have been identified in the past are handled by means of deployment turnover kits which are passed from the returning repair ship to the ship next scheduled to deploy. Examples are Rigid Inflatable Boat (RIB) repair kits and certain weapon repair packages. As ships use the parts in these kits, they replace the parts used, turning over a complete kit upon their return[21].

Pre-deployment load planning is expensive both in terms of funds committed and manpower. Items must be identified, reviewed, ordered, received and stored. At the end of the deployment material not used must be offloaded if procured with DBOF funds, or held if ordered or procured with ROV funds. While pre-deployment levels settings and the increased requisition priority given to deploying ships assist them in getting parts, the TARSLL as currently computed does not adequately address the problem of higher than normal demand encountered during a deployment.

[21]If parts are not available to complete the kit, an itemized list of deficiencies is given to the ship receiving the kit.

Current tender practices create additional problems by not accurately recording all demand.

E. RECOMMENDATIONS FOR IMPROVEMENT

1. Demand Recording

Repair Parts Petty Officers in the repair department already receive training to distinguish between recurring and non-recurring demand. More emphasis should be placed on distinguishing recurring demand from non-recurring demand with the benefits of correct entry explained to repair parts petty officers in training.

There are parameters in SUADPS to remove demand based items from the inventory of carried items if they meet certain criteria, however, SUADPS does not allow TARSLL items to be dropped from the inventory of carried items due to low demand.[22] A change in procedures which allows TARSLL items to be treated like demand based items (requiring one demand in six months vice one demand in two years used in the TARSLL model) will alleviate the problem of excess TARSLL stock.

Shop spares present a more difficult problem. They stem largely from a distrust of the load list and the supply department's ability to procure parts in a timely manner. As downsizing continues and parts tend to be shipped from activities not located on the waterfront, thereby lengthening order and shipping time, the negative perceptions by repair personnel will probably increase.

One solution to the shop spares problem is to have each tender set up a pre-expended bin program. All shop spares would be inventoried and turned in to the supply department, which would implement and run the program. Additional

[22]Allowance Type Code 2 (TARSLL items) cannot be deleted from the records.

manning would be needed in the repair department, but could come from a combination of supply department and repair department personnel, similar to the Hazmart operation.[23] All shop spares would have to be identified and consolidated in one location. Inventory records would have to be established and maintained. This would enable the TARSLL model to include these items in its candidate selection.

2. Candidate Selection

As previously stated, the bulk of TARSLL candidate selection is done at SPCC. While inputs are solicited and accepted from the Type Commander and the fleet, practical considerations make this method of participation less than adequate. In an effort to improve the process, COMNAVSURFLANT recently held a conference with SPCC to discuss TARSLL effectiveness [Ref. 7]. Several improvements to the candidate selection process were recommended and were being evaluated by SPCC. Before attending the conference, COMNAVSURFLANT solicited input from all tenders and encouraged them to send a representative to the conference if the tender's travel funds permitted. This type of meeting should be required on a triennial basis. In addition to supply personnel, repair department personnel should be required to attend. They are the personnel who see the problems on a daily basis and can explain why a particular part should be added or deleted from the TARSLL. Including Repair Department personnel would also help them see that they are a vital part of the process and would perhaps encourage them to be more meticulous about recording demand.

Additionally a written procedure should be implemented setting TARSLL problem reporting criteria and requiring written reports when problems are identified.

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[23]The Hazmart operation on a tender is manned by personnel from all shipboard departments that use Hazardous material in proportion to their percentage of usage. The repair department as the major user of Hazardous material, provides the majority of the personnel. The entire program is run by the Supply Department.

This does not have to be a complex report, perhaps just a comment at the end of each month's financial reporting message, similar to DLR and parts reutilization reporting requirements.[24] These reports could be sent to SPCC immediately for action to initiate interim TARSLL changes.

The Type Commander is given 30 days to review the preliminary TARSLL approximately 3 months before the scheduled implementation date. Upon receipt of the preliminary TARSLL a formal TARSLL review conference should be scheduled with tender supply officers and repair officers. The preliminary TARSLL is currently sent to the tenders for review, but workload has a negative impact on the quality of the review done. No written guidelines for TARSLL review exist and each ship is left to it's own devices as to how best to conduct the review. A conference to discuss the review process and identify perceived problems would allow personnel from each ship to review the TARSLL away from the distractions of their normal work environment and would help identify fleetwide problems. It would also allow attendees to refresh their memories concerning the review process. Participants could then go back to their respective ships, do the review as outlined and perhaps have a followup conference to discuss identified problems. Alternately the followup could be accomplished by means of a completion report in a format specified by the Type Commander.

3. Churn

SPCC's attempts to limit churn are working too well. The result of minimizing churn has been an increasing amount of excess material. The current range model does not take requisition rate or demand timing into account. Once on the TARSLL, the criteria necessary to remain there are even lower resulting in excess material. At

[24]COMNAVSURFLANT currently requires each tender to list any overdue DLRs and requires a summary of the dollar value of material procured via reutilization sources such as DRMO. A statement identifying TARSLL could be added as well [Ref. 8].

this point in time some measures will have to be taken to correct the problem of excess material retained on the TARSLL. Once excess stock has been identified and offloaded, churn parameters should be examined with an eye toward making retainability requirements more stringent. Some progress has been made in this area, with SPCC agreeing to retain only those items with a rate of demand of at least one requisition in eight quarters. SPCC has also shortened the period of demand included for BRF items (items with no demand history) to 8 quarters, thereby eliminating some items which would have been included in the past.

4. Deployment

Pre-deployment load out[25] is currently a largely manual process. One suggestion is that a separate TARSLL should be tailored specifically for deployment. The deployment TARSLL could take into account the availability of material from the Combat Logistics Force ships, raw material order and shipping time, and incorporate a load list for Gas Turbine repairs. An alternative to preparing a separate TARSLL for deployment would be for the Type Commander to compile a recommended load list for repair department shops and fund the purchase of the materials using ROV funds.

Excess materials at the end of the deployment should be turned over to the next deploying tender. An informal arrangement of this sort already exists within the repair community, with each deploying ship sending "lessons learned" to its relief and turning over excess raw materials if the relief is willing to take them. The alternative for many of these materials is to be turned in for scrap, with the resultant loss of funds.

[25]Pre-deployment loadout refers to the identification and procurement of stock items to support the tender's deployment.

Pre-deployment conferences are currently conducted by the overseas area coordinator. The returning deployer should send representatives to this conference to formalize the turnover of excess raw materials.

V. SUMMARY

A. FUTURE OF THE TENDER FLEET

The future of the tender fleet is uncertain at this time. Current plans call for four tenders to be located in the United States and one or two forward deployed in the Mediterranean at all times. Destroyer tenders (AD) and submarine tenders (AS) will cease to exist as separate load list types and will be replaced by a combined surface\ submarine tender.[26]

B. IMPACT ON THE TARSLL MODEL

The TARSLL was due to be revised in 1995. However, this activity has been placed on indefinite hold. There are two reasons for this. One is the uncertainty involving the numbers and homeports of the tender fleet due to downsizing. The other is the Type Commanders' perception that the current TARSLL is ineffective. Originally the Type Commanders requested and held a meeting with SPCC to discuss the perceived problems and to devise solutions. This meeting was held in October 1994, and the following corrective action was agreed upon:

1. Frequency of Demand

SPCC has agreed to adjust the model to include a range rule based upon the number of requisitions received for the material over some period of time in both the TARSLL candidate and TARSLL retention process. The range rule will require that an item experience at least one frequency of demand in the previous eight quarters. This change should eliminate some of the dead stock currently carried. Best Replacement Factor (BRF) items (those items with no demand history recorded) will have to have been added within the last eight quarters as well in order to be considered

[26] AS 33 and AS 40 currently carry a combined load list.

candidates for inclusion in the load list. This change will also reduce excess stock by reducing the number of items that become candidates.

The next TARSLL should be studied to determine whether these changes are enough to improve effectiveness. If the revised TARSLL does not significantly reduce the amount of dead stock on hand, the requisition frequency over time issue should be revisited to increase the range cut. With a frequency of demand range cut of one, the possibility still exists for one tender to order an item one or two times in large quantities and result in all tenders in that ocean carrying the item, resulting in excess material. A better correction would be to determine a mix between the frequency of demand and the number of tenders which experience that demand. Perhaps a range cut of one incidence of demand for at least two tenders, or even two incidences of demand for two tenders will give better results.

2. Reduction in the Number of Tenders

The reduction in the number of tenders will have the effect of increasing recorded demand across the board with a resultant decrease in dead stock even if no other corrective action is taken. As the number of tenders is reduced, there will also be a reduction in the frequency of demand recorded. Should future TARSLL models increase the frequency of demand range cut, this should be taken into account.

With fewer tenders in the fleet, the problems discussed in this thesis will be felt more keenly. The remaining tenders will have to carry the best load mix possible in order to meet their customers needs. TARSLL effectiveness will be an even more critical issue on the tenders carrying a surface/submarine load list. Every square inch of available storage space will have to be used to store active material. There will be little room for dead stock.

Implementation of the TARSLL model changes and tender procedural changes recommended in this thesis should correct the problems identified therein. These

problems should also be considered when developing the new model for the combined submarine/surface tender.

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